

# **Corner rounding in EUV photoresists: tuning through development time, PEB temperature, and platform constituents.**

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At the 2008 EUV Symposium it was shown that corners patterned in EUV photoresist often exhibit a rounding bias between inner and outer corners [1]. SEM metrology of the experimental EUV photo mask showed no corner rounding bias in the mask; modeled aerial images assuming a thick mask (multilayer + absorber) revealed no aerial image bias; and various EUV resist blur models including PROLITH, single blur [2] and dual blur [3] models could not reproduce the experimentally observed bias. Today, the source of the corner rounding bias remains unknown.

Table 1 shows the average radii of inner and outer corners in Resist A as development time is varied from  $<<1$  second to 3 seconds in 1-second intervals. Within the first three seconds of development the average inner and outer radii of Resist A increase by 19% and 13%, respectively, with a corresponding 25% increase in 50 nm 1:1 LER. These data warrant a more complete investigation of the EUV development process and how it affects the fidelity of corners and patterning in general. In this paper the corner rounding bias, deprotection blur, and LER of three of today's leading chemically amplified EUV photoresists is monitored as development time and post-exposure bake (PEB) temperature are varied. In addition, the same performance metrics of an experimental EUV resist platform are monitored as base and photo acid generator (PAG) size and weight percent are varied. All experimental results are compared to predictions from PROLITH PEB and development models and similarities/differences between the two are elucidated. This work was supported by the Director, Office of Science, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Dev. time (sec)	Inner radius (nm)	Outer radius (nm)	LER (50 nm 1:1)	LWR (50 nm 1:1)
<<1	59	46	3.9	5.7
1	61	47	4.2	6.6
2	64	47	4.35	7
3	70	52	4.9	8.4

Table 1: average radii of inner and outer corners in Resist A as development time is varied. The reported corner radius is the average radius of all 7 corners in the 700 nm elbow pattern shown in Figure 1. Line-edge-roughness (LER) and line-width-roughness (LWR) of 50 nm 1:1 lines is also included for completeness. All resists were exposed to EUV radiation at the 0.3 numerical aperture SEMATECH Berkeley Microfield Exposure Tool (BMET) printing facility at the Advanced Light Source at Lawrence Berkeley National Laboratory (LBNL) using conventional  $\sigma = 0.35 - 0.55$  annular illumination.

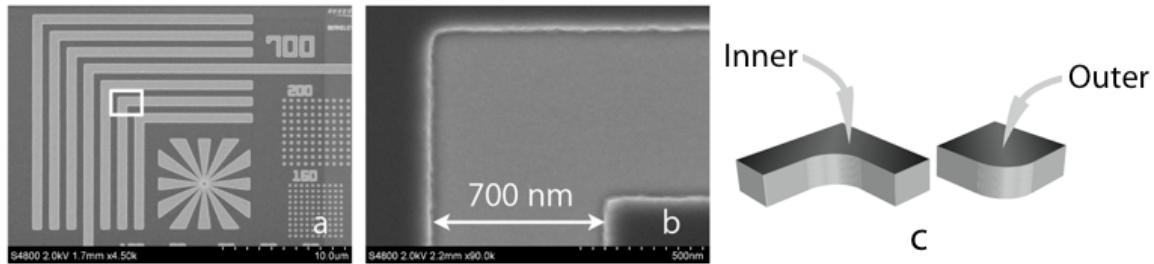


Figure 1: a) SEM image of a 700 nm elbow pattern - dark areas are resist, light areas are wafer; b) high-magnification image of the boxed region in (a); c) visual comparison between inner and outer corners - the material is resist

## References:

- [1] C. Anderson, T. Wallow, and P. Naulleau "Corner rounding in photoresists for extreme ultraviolet lithography," Oral Presentation, 2008 EUV Symposium, October 2008.
- [2] C. Anh, H. Kim and K. Baik, "A novel approximate model for resist processes," Proc. of SPIE Vol 3334, pp. 752-763 (1998).
- [3] Y. Tanaka, Y. Kikuchi, D. Goo, H. Oizumi, and I. Nishiyama, "Estimation of diffusion lengths of acid and quencher in chemically amplified resist on the basis of extreme ultraviolet exposure results," JVSTB 25(6) Nov/Dec 2007.